Lamprey early life history: thermal ecology of Columbia River Basin lampreys

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U.S. Geological Survey

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Acknowledgements

- Bonneville Power Administration
  - Project # 2000-02900
  - Debbie Docherty
- U.S. Fish and Wildlife Service
- Confederated Tribes of the Umatilla Indian Reservation
- U.S. Geological Survey

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Importance of examining temperature affects

- Essential for understanding the basic biology of a species
  - Influences development, survival, and fitness
- Provides insight into more complex issues
  - Determines habitat quantity and quality
  - Population dynamics

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Factors influencing stream thermal regimes

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Purpose of study

- Examine the effects of temperature on survival and development of Columbia River Basin lampreys
  - Treatments: 10° C, 14° C, 18° C, 22° C
  - Embryos and early stage larvae
  - Pacific lampreys (*Lampetra tridentata*)
  - Western brook lamprey (*Lampetra richardsoni*)

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Study organisms

- Native to the Columbia River Basin
- Believed that population size is declining

Pacific lamprey

Western brook lamprey

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Methods

- Wild animals
- Gametes were removed
- Eggs were fertilized
- Temperature was adjusted over 0.5 hours
  - 10° C, 14° C, 18° C, and 22° C
- Fertilized eggs were placed in rearing jars
- Allowed to develop for 15 Temperature Units (TU)
  - TU = (days) x (degrees above 0° C)

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Methods

- 100 viable embryos were placed into each of 10 cups per temperature
  - Sterilized water
  - Natural photoperiod
  - Monitored water quality

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Methods

- Each day
  - All cups were examined
    - Dead embryos/larvae
    - Hatched lampreys
    - Abnormal larvae

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Temperature unit model

- Logistic regression was used to estimate the mean time to 50% hatch for each species/temperature
- Mean time to 50% hatch converted to development rate to 50% hatch
  - Linear regression model
    - Effect of temperature on development rate to 50% hatch

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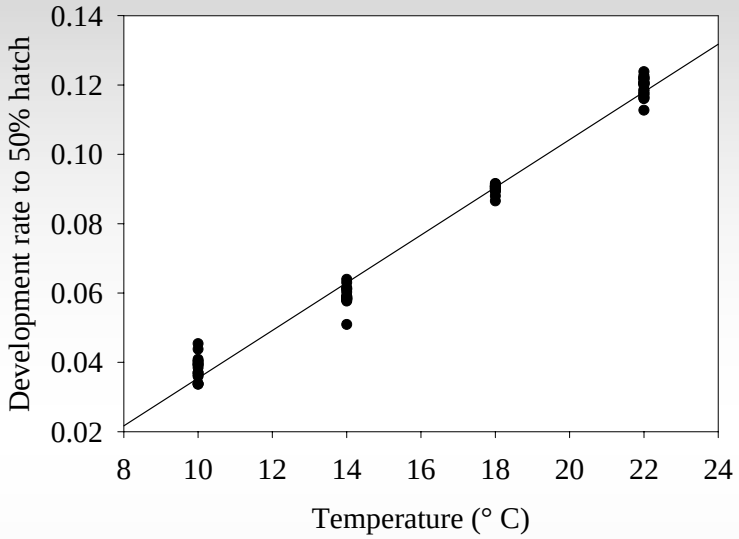
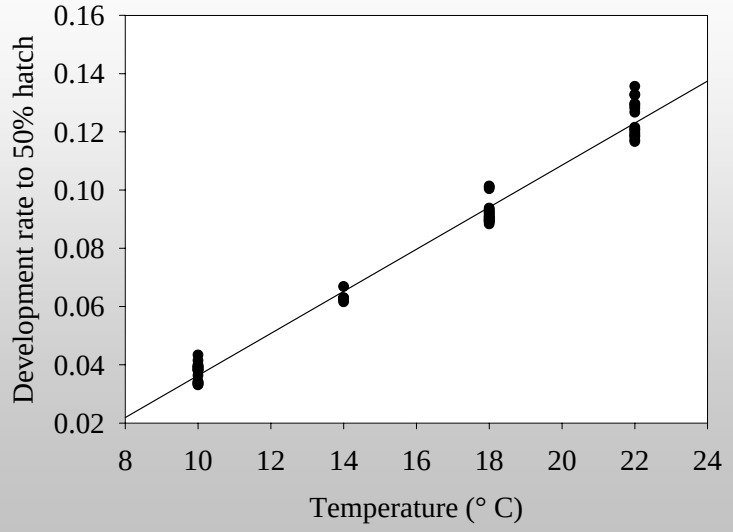
Temperature unit model



- Pacific lamprey
  - y = 0.007x – 0.033
  - $r^2 = 0.99$
  - $P < 0.0001$



- Western brook lamprey
  - y = 0.007x – 0.036
  - $r^2 = 0.98$
  - $P < 0.0001$

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Temperature unit model

Species	Temperature (° C)	E_T (° C)	D_{H95}	Accumulated TU
Pacific lamprey	10	5.15	29.26	150.7
	14	9.15	18.85	172.5
	18	13.15	12.22	160.7
	22	17.15	9.08	155.7
Western brook lamprey	10	5.03	29.34	147.6
	14	9.03	17.00	153.51
	18	13.03	11.90	155.1
	22	17.03	9.03	153.8

- Standardizes effects of temperature and time
- Allows for comparisons among individuals at similar developmental stages regardless of thermal exposure

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Data analysis: survival

- Analysis of Variance (ANOVA) $\alpha = 0.05$
  - Effect
    - Temperature
    - Species
    - Accumulated TU (95% hatch, larval stage)
      - 95% hatch ≈ 155.6 ± 10.8 TU
      - Larval stage ≈ 294.0 ± 10.2 TU
  - Response
    - Proportion of individuals surviving
      - Arcsin transformed to stabilize variance
    - Bonferroni *t* statistic when overall model was significant

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Data analysis: survival

- Year group
  - $F_{1,248} = 2.02$, $P = 0.1563$
- Species X temperature
  - $F_{3,116} = 1.20$, $P = 0.3140$
- Temperature X accumulated TU
  - $F_{3,120} = 1.56$, $P = 0.2039$
- Species X accumulated TU
  - $F_{1,120} = 19.0$, $P = 0.1709$

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Main effects: survival

- Temperature
  - $F_{3,116} = 198.47$, $P < 0.0001$
- Species
  - $F_{1,116} = 5.22$, $P = 0.02$
    - Pacific lamprey = 82.8%
    - Western brook lamprey = 84.4%
- Stage
  - $F_{1,120} = 53.77$, $P < 0.0001$
    - 95% hatch = 85.1%
    - Larval stage = 82.0%

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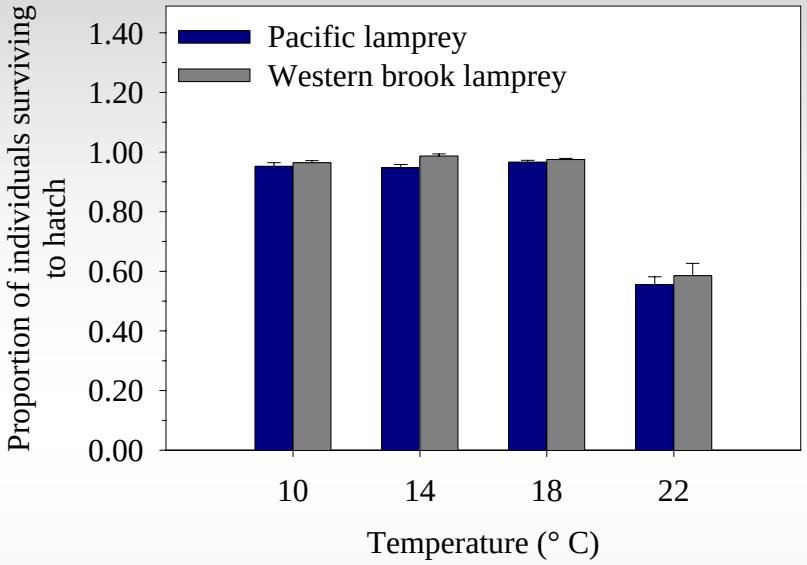
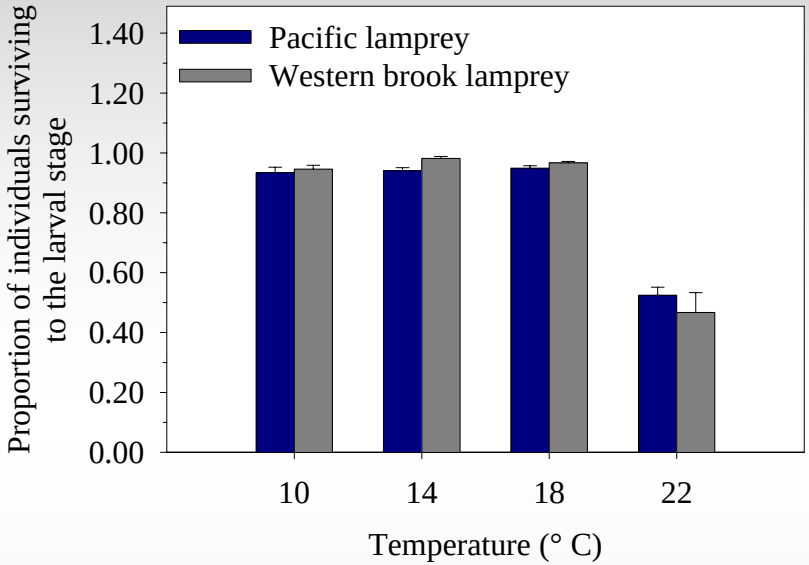
Mean comparisons: survival





- 22° C vs.:
  - 10° C (t = 19.38, df = 116, $P < 0.0001$)
  - 14° C (t = 15.82, df = 116, $P < 0.0001$)
  - 22° C (t = 21.40, df = 116, $P < 0.0001$)
- All other comparisons ($P > 0.05$)

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Data analysis: abnormalities

- Analysis of Variance (ANOVA) $\alpha = 0.05$
  - Effect
    - Temperature
    - Species
  - Response
    - Proportion of larvae ($\approx 294.0 \pm 10.2$) TU exhibiting abnormalities
      - Square-root transformed to stabilize variance
    - Bonferroni *t* statistic when overall model was significant

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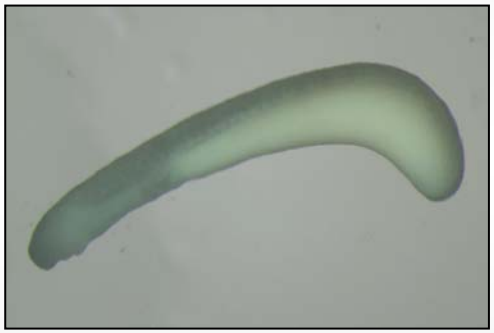
Methods

- Normal larvae



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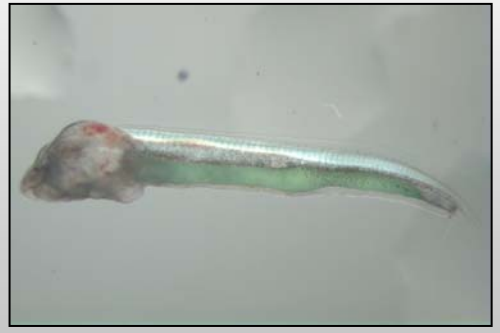
Methods

- Abnormal larvae



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Data analysis: abnormal

- Year group
  - $F_{1,118} = 0.75$, $P = 0.3871$
- Species X temperature
  - $F_{3,111} = 2.33$, $P = 0.08$
- Temperature
  - $F_{3,111} = 127.49$, $P < 0.0001$
- Species
  - $F_{1,111} = 0.33$, $P = 0.56$

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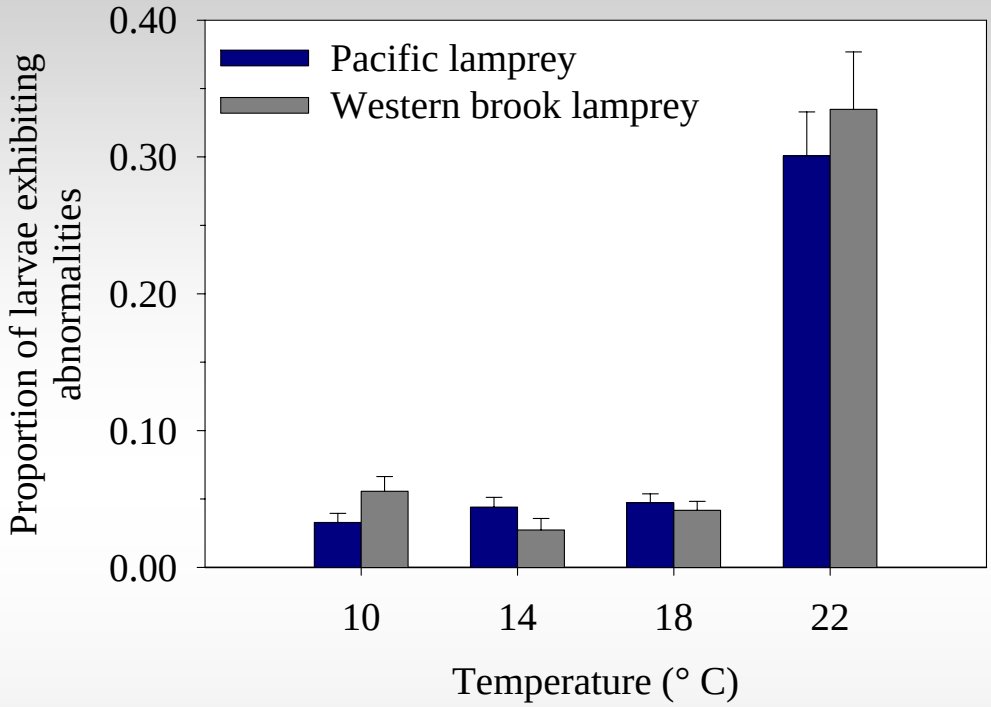
Mean comparisons: abnormalities



- 22° C vs.:
  - 10° C (t = -15.38, df = 111, $P < 0.0001$)
  - 14° C (t = -13.61, df = 111, $P < 0.0001$)
  - 22° C (t = -16.36, df = 111, $P < 0.0001$)
- All other comparisons ($P > 0.05$)

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Conclusions

- Survival to 95% hatch and to the larval stage were significantly less at 22° C than at other temperatures examined for both species
- Significantly more larval abnormalities occurred at 22° C than at other temperatures examined
- Optimal temperature range: 10° C - 18° C
  - High survival rates and normal development
- Provide insight into defining habitat requirements for early life stage lampreys in the Columbia River Basin

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Future directions

- Field based examination of thermal requirements
  - Distribution
  - Reproductive timing
- Thermal requirements of other life stages
  - Migratory stages

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